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DEVELOPMENT OF SILICATE RESEARCH AND TECHNOLOGY  
IN CHINA DURING THE PAST DECADE

-COMMUNIST CHINA-

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DEVELOPMENT OF SILICATE RESEARCH AND TECHNOLOGY  
IN CHINA DURING THE PAST DECADE

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China is traditionally credited by the world with the invention of porcelain ware. More than a thousand years ago, our ancestors had already mastered the technique of manufacturing chinaware, produced porcelain ware of a high standard and high technical level and contributed significantly to the civilization of mankind.

Because of prolonged feudal rule, especially the imperialistic encroachments of the past century, the development of a silicate industry and technology in China was greatly restricted and undermined, but its development and growth has been rapid with the expansion of socialist economic reconstruction under the endorsement and support of the party and government after the liberation.

During the economic rehabilitation period from 1949 to 1952, all branches of the silicate industry were revitalized and their production capacity increased. Measures were taken to improve their quality and new products issued from the production lines to meet the nation's construction needs for other industries.

After 1953, during the period of the first five-year plan, various branches of the silicate industry underwent tremendous changes. To begin with, important raw material bases were explored and evaluated; new modernistic factories were planned and constructed; and a number of outdated works were remodeled and extended. During these five years, production increased and quality improved; many new products were developed and the coefficient for equipment utilization also improved from year to year.

During 1958, China's great leap forward year, the silicate industry expanded with unprecedented speed. Compared with the figures for 1957, the production of fire-resistant material increased two times, and a production

record of 9,300,000 tons of cement per annum was attained, which is illustrative of the general rate of growth. The meteoric expansion of the silicate industry engendered a stimulating effect on silicate technology and development. At the same time, the attainment of this development cannot be separated from the pursuit of scientific research. During the past decade the growth of technological strength has been tremendous. Special silicate courses were offered in seven colleges for the training of silicate specialists and many new research organizations were founded. An Institute for Chemical and Industrial Silicate Research (Kuei-suan-yen hua-hsueh yu kung-hsueh yen-chiu-so 9701, 6808, 7770, 0553, 1331, 5280, 1562, 1331, 4282, 4496, 2076) was founded under the auspices of Academia Sinica. Planning and research organizations, such as cement, fiber ceramics and fire-proof material laboratories, were established by various industrial departments. Many achievements were made in silicate production and technology during the past decade.

### I. Cement

To accelerate the growth of the cement industry, raw material bases must first be established and resources be fully utilized. Natural resources such as limestone of high magnesium content, flinty limestone, anhydrite, argillaceous gypsum, etc., are found in great abundance in China, and at the same time industrial wastes such as blast furnace slag, clay iron stone from the aluminum smelting industry, oil shale and dry distillation wastes are increasing in quantity from year to year. [In the past,] these resources and industrial residues were seldom used in the cement industry. After 1950, research on the problem was carried out and the application of these resources to the production of cement was systematized contributing in an important way to the rapid development of the cement industry.

Three of the new types of cement developed are silicic (Portland) cement, alumina cement and unwrought cement. These have now been placed in normal production.

Thus, alumina cement was first produced in a rotary furnace in which alumina raw material of high aluminum content was reduced. This was followed by the manufacture of unshrinkable, impermeable cement, aluminate expansion cement, gypsum expansion cement, etc.

In the case of silicic cement, apart from the production of mineral ore silicic cement, volcanic ash silicic cement and composite silicic cement, several special types of silicic cement such as white cement for decoration, cement for sealing oil wells, efflorescent cement, sulfate-

resistant cement, plastic cement, quick-setting ferrous silicate cement, quick-setting mineral residue cement, low temperature dike-building cement, road construction cement, etc., were developed.

The development of clay iron sulfate cement illustrated well the features of unwrought cement, which was manufactured by adding granular blast furnace slag, wrought gypsum and lime to clay iron stone residues from the aluminum smelting industry. At the laboratory more than 700 separate varieties were scheduled for trial production. They possessed low hydrothermal qualities and high permeability and resistance to corrosion. This new-type unwrought cement will be greatly developed with the rapid expansion of the aluminum smelting industry in China.

Furthermore, gelatinous materials that were locally available were greatly developed during the past few years, especially in 1958. The stimulating effect produced by research on this new type of cement and by its successful production on national economic construction were obvious.

It should be mentioned here that any improvement in cement production techniques is reflected in a rise in the production capacity of rotary furnaces and crushing machines. Toward the end of 1958, 50 percent of the furnaces in operation had already exceeded the originally planned production capacity by 30 percent and over 16 percent of the operating units had passed the planned figure by 50-75 percent. Average production volume per unit area had reached the respective levels of 24 and 60 kilograms per square meter per hour for "dry method" and "wet method" furnaces.

## II. Fire-resistant Materials

Following the liberation, the rapid growth of the fire-resistant material industry was closely associated with the expansion of the iron and steel industry. Chronologically speaking, the utilization of pure quartz ( $\text{SiO}_2 > 99\%$ ,  $\text{Al}_2\text{O}_3 < 0.3\%$ ) for the production of completely unwrought silicic bricks of high silicon content for horizontal furnace ceiling construction ranked first among all important technological accomplishments. By adding an adequate amount of ore-reducing agent and by rigidly controlling production procedures, the finished product had already reached this level:  $\text{SiO}_2$ , 97~98%; porosity index, 12-15%; fire-resistance,  $1710-1730^\circ\text{C}$ ., weighted initial softening point (2 kilograms per square centometer),  $> 1670^\circ\text{C}$  and true specific gravity, 2.33-2.34.

Next in importance was the utilization of alumina material of high aluminum content, found in great abundance

in China, for the production of aluminum bricks. After two years of testing and trial manufacture, natural resources found in different localities were employed in 1954-1955 for the production of various kinds of aluminum brick which proved to be generally satisfactory for metallurgical use. When used for electric furnace ceilings, it was 2-5 times more durable than silicic brick. For medium-sized electric furnaces built with this material the highest figure reached was 855 units. It was successfully employed for the building of giant blast furnace grates, molten steel buckets, cast metal stoppers, cement rotary furnace grates and high temperature tunnel kiln ceilings.

Extensive examination of the mineral composition of alumina of high aluminum content and its combustion characteristics was undertaken. This raw material, found in various localities, was mainly composed of diaspore and kao-linite at times interspersed with "po-mei" rock and mineral matter. The pure material consisted entirely of diaspore of high  $TiO_2$  content but with complicated combustion characteristics. It was principally comparable to  $Al_2O_3/SiO_2$  in proportion or closely identified with the formation of secondary "mo-lai" /monetite ?/ rock. Sample bricks from electric and horizontal furnace ceilings were subjected to a metallurgical test to ascertain the cause of mechanical breakdowns and to devise ways and means for improvement. In the sample bricks were observed traces of schistose "ho-po-mo" rock  $[(Fe,Mg)_6(Al,Fe)_{16}TiO_{32}]$ , whose formation was definitely linked to a sheet exfoliation phenomenon as seen on the ceilings of brick furnaces while they are in operation. Special research was undertaken to explore the possibility of selecting bricks of high aluminum content for furnace gratings in blast furnaces designed for the reduction of iron ore containing fluorine. By means of tests in a blast furnace and specially planned laboratory tests, it was preliminarily established that the fluorine found in the furnace had caused its surface to erode and its gratings to disintegrate. Minerals such as fluorite, fluoric mica, potassium (sodium) nepheline, leucite, spear pyrite etc. caused the body of the furnace and its brick lining to wear away. For the first time mineral mica was discovered in the furnace. In the temperature that prevailed in the upper and middle part of the furnace, the formation of fluoric magnesium mica served to stabilize such ions as  $F^-$ ,  $K^+$  and  $Ca^{++}$  and to afford protection to the brick lining. While a sizable amount of fluorine would accumulate on the brick surface and in the body of the furnace, little would be found in molten form because of the low temperature, and its corrosive effect on the brick lining could not be

serious. But in view of the 20-25 percent fluorine content in the furnace slag, no silicic aluminum fireproof material could withstand its corrosive effect. Hence, it was proposed that the furnace base and body be lined with carbon bricks.

The successful development of aluminum-magnesium bricks\* for lining horizontal furnace roofs with an alkaline substance was considered as the third achievement in the field of fire-resistant material production calculated to fit in with the resource situation in China. They were square magnesium bricks with spinel, formed when the brick biscuits were being fired, as the basic component. The presence of spinel helped lower the coefficient for heat expansion and molding elasticity, contributing greatly to the stabilization of thermal energy.

By lining horizontal furnace roofs with aluminum-magnesium bricks produced by the Chungking Iron and Steel Mill (Ch'ung-Ch'ing Kang-Tieh Kung-Szu 6850, 1987, 6921, 6993, 0361, 0674), excellent results were obtained. The life span of its medium-sized horizontal furnace was noted to be 623 times firings; it was 520 times firings when applied to the giant open hearth maneuverable horizontal furnace of the Anshan Steelworks. In a comparable test, it was revealed that the average depreciation per batch for chromium-magnesium brick was 0.43 millimeter as against 0.21 millimeter per batch for aluminum-magnesium brick.

It was also observed after testing used sample bricks that symptoms of sheet exfoliation were less in aluminum-magnesium bricks than in chromium-magnesium bricks. Again, oxidation was confined to the operating area and at the same time aluminum-magnesium brick was less sensitive to oxide than chromium-magnesium brick. It was observed that cracks were present only in areas remote from the zone of immediate operation, testifying to the fact that sheet exfoliation would occur only after protracted operation. With the exception of the first batch,  $Al_2O_3$  was definitely reduced. The presence of spinel was immaterial so long as there were no noticeable fluctuations in subsequent batches apart from spinel crystallization through oxidation. This maintenance of operation demonstrated the superior quality of aluminum-magnesium brick.

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\* Aluminum-magnesium brick refers to magnesium brick containing oxide of aluminum; chromium-magnesium brick denotes magnesium brick containing chromite; this connotation applies to other similar expressions.

Finally, the trial manufacture of "mo-lai" (monetite?) rock brick and its entry into production should be mentioned, for it altered the import situation of important fire-resistant material by the glass industry.

### III. Glassware

Technological achievements in glass making during the past decade can be evaluated first by the improvement in production technique and second by the development of such new lines as precision glass. The capacity for molten glass in the furnaces increased from 0.913 ton per square meter per day and night in 1952 to 1.302 ton per square meter per day and night in 1958. Average production speed per batch rose from 85.69 meters per hour in 1952 to 106.89 meters per hour in 1958. A speed of 130 meters per hour was reached and maintained by the most advanced operating unit.

Manufacturing methods for several score of new products having different optical constants and using flint optical glass were developed and systematized. Optical glass with high refraction of light and low dispersion of colors was studied and developed. In addition, 2-meter astronomical mirror reflectors were successfully trial produced. The production rate for high quality optical glass increased during the last few years with improvements in testing and production techniques. For example, Jena glass rose from a low of 15 percent in 1953 to a high of 35-40 percent in 1958.

A great deal of theoretical research on optical glass was done. From practical data on the chemical composition, density, light refraction rate and color dispersion of the most used glassware were evolved sets of chemical formulas for computing its physical properties. The effects of oxides in glass such as  $P_2O_5$ ,  $La_2O_3$ ,  $TaO_2$ ,  $ZrO_2$ ,  $GeO_2$  and  $TeO_2$ , on light refraction rates and color dispersion coefficients were ascertained by testing and statistical methods. Research and surveys were undertaken to determine the ternary aspect of  $P_2O_5$ -  $B_2O_3$ -  $BaO$ ,  $La_2O_3$ -  $B_2O_3$ -  $CdO$ ,  $ThO_2$ -  $B_2O_3$ -  $CdO$ , etc. in influencing the scope of glass formation and its optical constant. Subjects such as the reduction of firing speed, temperature and its intensity, light refraction rates and infrared ray absorption limits were discussed. Valuable results were obtained.

As to precision glass, a series of color filter glasses (including infrared ray and ultraviolet areas) and X-ray absorption lead glass were developed. The production of glass with high silicon oxide content was also examined in great detail. Subsequently, the ratio between  $Na_2O/B_2O_3$  in

primary glass and  $\text{Na}_2\text{O} - \text{B}_2\text{O}_3 - \text{SiO}_2$  of the ternary system was ascertained, and their relationship to silicon oxide content after heat treatment was also established. The effect of a small quantity of  $\text{Al}_2\text{O}_3$  on phase splitting and its influence on the properties of glass of high silicon oxide content were tested. By examining how viscosity of primary glass of the ternary series changed with time during firing, the relationship between phase splitting and temperature was established. By computing data on its active potential, it was ascertained that the phase splitting process was self-starting.

To meet the requirements for new technological development during the great leap forward in 1958, high frequency electric furnaces and carbon-resistant furnaces were one after another systematized, and an oxy-hydrogen flame device was employed for producing transparent and semi-transparent quartz glass. During the past few years glassware for technical uses, such as hard chemical glass, thermometer glass, electrode glass and neutral and alkali-resistant glass were thrown into production one by one.

The development of the fiber glass industry began in the early period of the first Five-Year Plan. To provide electric insulators with a continuous supply of high-quality glass fiber, the production of alkali-free boric glass fiber and borax and alkali-free material was successfully initiated. In 1958 fine fiber of 3-5 millionths of a meter was drawn for weaving fiber glass cloth and cord. Also, different grades of fiber glass cotton were experimentally produced with success and fiber glass steel of all kinds also came off the production line. This material was made of compressed layers of organic resin.

#### IV. Ceramics and Porcelain

Notable progress was made in the manufacture of fine porcelain and industrial ceramics. In order to restore and raise China's world-wide traditional reputation for quality porcelain ware of all kinds and to put this industry on a scientific basis, research on production techniques in respect to biscuit, glaze and specifications for color and ingredients was started in 1953 at Ching-te-chen (2529, 1795, 6966) where fine porcelain representative of China was produced. The result was that the almost lost art of producing "lung-ch'uan", "chi-hung" ox blood, "chun-hung" Sung Dynasty red, "mei-jen-chi" beauty pink, "ch'a-yeh-mo" tea dust green, "wu-chin" black gold and some ten other varieties with typical Chinese Colors and glazes had been revived. The composition of the porcelain ware traditionally identified with Ching-te-chen since the days of the

Ming and Ching dynasties in respect to raw materials and biscuit and the chemical ingradients of the minerals used for preparing glazes clearly indicated that damourite was used instead of feldspar for the sake of hardness. In other words, the biscuit and the glaze came under the category of kaolinite-quartz-damourite and lime-quartz-damourite, the last mentioned mineral functioning as a joint dissolving agent. Tests proved that the specification for biscuit preparation included 50-60 percent kaolinite so as to alter adequately the composition of the glaze. The firing temperature was increased to about 1350° C. to improve the quality of the porcelain produced. The macroscopic structure of the biscuit showed a better development of "mo-lai" /monetite?/ rock crystals, a higher glass content and a more even distribution of finer quartz granules. The mechanical properties of the biscuit were further improved upon and its whiteness exceeded China's time-honored standards, and was higher than the level maintained abroad.

REpresentative samples of Chinese porcelain, China's valuable heritage, were scientifically examined, beginning in 1957, in order to ascertain their development. This work is being continued. For example, by analyzing "ch'ing-hua" /blue/ samples of the Ming and Ching periods it was established that their chemical composition varied as the raw materials varied, which accounted for the characteristics indentified with each period.

The development of high pressure electrical porcelain in 1953 was of importance for the ceramics industry, intended as it was for the manufacture of high pressure electrical porcelain with such raw materials as were procurable in the localities concerned in order to meet the demand for long-distance transmission of high-tension power. These objectives were satisfactorily fulfilled, and the production of electrical appliances such as 110 kilovolt stick insulators, large-size electric cable sleeves, 330 kilovolt capacity-type transformers, large-size sleeves, etc. was begun.

In 1958 research on a new type, high intensity, high pressure electrical porcelain of high aluminum oxide content was successfully carried out. The bending strength of unglazed porcelain was placed at 1900 kilograms per square centimeters, and its puncture pressure was as high as 40 kilovolts per millimeter. A 330 kilovolt air compression circuit breaker porcelain sleeve thus produced was capable of withstanding atmospheric pressure above 180.

The production of two types of ceramic cutting

blades was regarded as a triumph for the ceramics industry. Type One had a volume density of 3.92- 3.95, a hardness of RA 92- 93.5 and a bending strength of 3,500- 4,000 kilograms per square centimeter; and type two had a volume density of 3.86 -3.88, a hardness of RA 90 92 and a bending strength of 3,000 -3,500 kilograms per square centimeter. Because of its simple production technique, type two is now being manufactured. It is comparable to a cutting blade made of a hard metal alloy and is adapted to high speed cutting (300-400 meters per minute or better). In 1958, a metallic ceramic cutting blade compounded with a small amount of metal came off the production line. It was superior to steel alloy porcelain blades in cutting power and showed better performance in withstanding friction during high-speed cutting.

Other items of ceramic porcelain that were successfully trial-produced during the past few years included sanitary porcelain, ceramic radiator blades, acid-resistant bricks, high temperature furnace piping and thermo-electric couple protecting sleeves. Thus, the demand for rapid development of national economic construction was satisfactorily met.

During the past decade, rapid development of silicate technology outdistanced any in the history of China, transforming the backward appearance of the silicate industry which Old China had handed down and laying a firm foundation for its further advancement.

Naturally, compared with the work which we shall continue to perform in the years to come, the accomplishments thus far are merely a good beginning. Under the socialist system, all elements needed for high speed industrial growth are already present. We believe we must continue to exert ourselves in the decade to come so that more work may be accomplished with greater speed.

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